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IDENTIFICATION OF CRITICAL COMPONENT TO ENHANCE EQUIPMENT AVAILABILITY IN A GRAPHITE MANUFACTURING INDUSTRY

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ABSTRACT

The need of making appropriate decision in less time is arises day by day due to increasing competition, need of bottleneck production, high quality standards, awareness in customer and globalization. A small mistake may result in hefty production losses and reputation. Apart from this, generally a limited budget allocated to maintenance department. Therefore, it is necessary to use decision making techniques to ensure right decision at right time instead of relying merely on experience. The objective of present work is to identify Critical Component of Compressor using improved preference ranking organization method for enrichment evaluations (PROMETHEE) to ensure maximum equipment availability for production in a heavy industry.

KEYWORDS: Decision Making, Availability, PROMETHEE & Maintenance

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Original Article

INTRODUCTION

We all makes some types of decision (Thomas L. Saaty, 2008, Thomas L. SAATY, 2004, M.C. Carnero, 2005, 3, Rakesh Kumar Singh et al., 2013, Gabriel Iulian Fântână et al., 2013) every moment, in our day to day life either it may be selection of cloths for office or selection of most critical equipment for maintenance. To make a decision we need to know the problem, objectives, criteria and alternatives to select from and for this we collect information. This helps to understand events in order to comprehend and judge them. It is well known fact that not all information is useful. There are several examples are available that shows, too much information is as bad as little information therefore one or more pass points created to convert unprocessed data into tidy data.

Multiple-Criteria Decision Making (MCDM) (Devarun Ghosh et al., 2010) is useful when alternative with unsurpassed values are not available as each alternative scores high in some criteria, but less in some other criteria. It (Gabriel Iulian Fântână et al., 2013, Abbas Toloie-Eshlaghy et al. 2011) allows decision makers to rank alternatives by considering multiple conflicting criteria's.

Preference ranking tools (Rao et al., 2009, Prasenjit Chatterjee et al., 2012) are unique MCDM methods in which the alternatives judge against alternatives while making the matrix for a particular attribute. It requires preferences information among the instances of an attribute and across the existing attributes. The decision maker may convey or define a ranking for the attributes as importance/weights. The intent is to obtain the most excellent alternative that has the maximum degree of satisfaction for all the pertinent attributes.

PROMETHEE is an outranking method for a finite set of alternative to be ranked and preferred among criteria, which are often contradictory. Here in this paper improved PROMETHEE (Rao et al., 2009) method where analytical hierarchy process (AHP) applied for calculating weights and then, these weights applied with

PROMETHEE method for the recognition of critical component of compressor to improve machine availability in a manufacturing industry.

METHODOLOGY

(Rao Et Al., 2009; Chatterjee Et Al., 2012; Serafim Opricovic Et Al., 2007; Majid Behzadian Et Al., 2010)

This section covers the improved PROMETHEE methodology and below figure 1 shows the applied steps for this research work to identify critical component of compressor which is located in a graphite manufacturing industry.

Figure 1: Flow Chart for Critical Component Identification for Compressor

Step 1: Calculate weights of the criteria using AHP method

- Evaluate the geometric mean of each row and add all the geometric means of decision matrix.

$$GM_J = \sqrt[M]{[\prod_{J=1}^{M} k_{ij}]} \tag{1}$$

$$w_j = GM_J / \sum_{J=1}^{M} GM_J \tag{2}$$

- Check pair-wise comparison matrix for consistency and also calculate the weight of different criteria then, Make

A_2 with the help of w_j values.

$$A_2 = \begin{bmatrix} w_1 \\ w_2 \\ - \\ - \\ w_j \end{bmatrix} \quad A_3 = A_1.A_2 \quad A_4 = A_3/A_2$$

- Determine the maximum Eigen value λ_{max}, consistency index and consistency ratio.

  CI= (λ_{max} - M)/ (M – 1) (3)

  CR=CI/RI (4)

Step 2: Compare alternatives pair-wise with respect to every single criterion, and express the results are as preference functions. The multiple criteria preference index Π_{a1a2} is subsequently defined as the weighted average of the preference functions P_i:

$$\Pi_{a1a2} = \sum_{i=1}^{M} w_i P_{i,a1a2} \tag{5}$$

Π_{a1a2} Shows the amount of preference of the decision maker of alternative a1 over alternative a2, when considering simultaneously all the criteria and its value ranges from 0 to 1.

Weighting coefficients (weights w_i) introduced to express the relative significance of different criteria.

Step 3: Find the sum of each row and each column in the overall matrix

$$\varphi^+ (a) = \sum_{x \varepsilon A} \Pi_{xa} \tag{6}$$

$$\varphi^- (a) = \sum_{x \varepsilon A} \Pi_{ax} \tag{7}$$

φ^+ (a) and φ^- (a) are known as the leaving flow and the entering flow respectively. The leaving flow denotes domination of an alternative over the other alternatives, while the entering flow expresses domination of other alternatives over that alternative.

Step 4: The difference between the corresponding row and column provides the score for the alternatives. Calculate the net outranking flow, $\varphi(a)$ for each alternative.

$$\varphi(a) = \varphi^+ (a) - \varphi^- (a) \tag{8}$$

Step 5: Position the values of $\varphi(a)$ in the decreasing order and accordingly provides the ranking of the alternatives. The higher is the value of $\varphi(a)$ the better is the alternative.

PROBLEM ANALYSIS

This section covers the analytical part of this industrial problem. The attributes preferred for this work are based on two principal factors, viz. internal procedures deficiency and plant maintenance priorities. The attributes are as follows-

- **Total Number of Failures per unit Time (In Numbers):** Shows how many times failures occurred in FY 2015-16

- **Quantity of Spares (In Numbers):** Shows quantity of spares issued by mechanical maintenance department in FY 2015-16
- **Spare Part Cost (**INR**):** Spare part cost in Indian Rupees

Table 1: Attributes and Their Values

Name	ID	Total Number of Failures per unit Time (In Numbers)	Quantity of Spares (In Numbers)	Spare Part Cost (Lac Indian Rupees)
Check Valve	**CV**	10	70	65053.83
Inlet valve	**IV**	16	123	53871.3152
Compressor Element	**CE**	29	83	445560.952
Safety Valve	**SV**	8	20	7297.01
Solenoid Valve	**Y1**	6	28	64841.6
Outlet Valve	**AV**	11	150	27038.77

Weightage Calculation

Table 2: Random Index

Attributes	3	4	5	6	7	8	9	10
RI	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

The A1 shows Correlation Matrix-

$$A_1 = \begin{array}{cccc} \textbf{Attributes} & \textbf{TNF} & \textbf{QOS} & \textbf{SPC} \\ \textbf{TNF} & 1 & 5 & 3 \\ \textbf{QOS} & 1/5 & 1 & 1/4 \\ \textbf{SPC} & 1/3 & 4 & 1 \end{array}$$

By using equation (1)-(2) evaluation of weights of different criteria was conducted which was shown by matrix A_2, and then we have evaluated the values of A_3 and A_4 as-

$$A_2 = \begin{bmatrix} 0.626696471 \\ 0.093616018 \\ 0.279687511 \end{bmatrix} \quad A_3 = A_1.A_2 = \begin{bmatrix} 1.93383909 \\ 0.28887719 \\ 0.86305041 \end{bmatrix} \quad A_4 = A_3/A_2 = \begin{bmatrix} 3.08576669 \\ 3.08576669 \\ 3.08576669 \end{bmatrix}$$

We have obtained consistency index (CI) as 0.04288335 by using equation 3 and we get value of random index (RI) for 3 attributes as 0.52 from Table 2. While considering ratio of CI and RI we have evaluated the value of consistency ratio (CR) as 0.08246797 by using equation 4. As CR is less than, equal to 0.1 therefore the calculated weights W_{TNF} = 0.626696471, W_{QOS} = 0.093616018and W_{SPC} = 0.279687511are acceptable.

PROMETHEE Approach

Table 3: Total Number of Failures per Unit Time

	CV	IV	CE	SV	Y1	AV
CV	*	0	0	1	1	0
IV	1	*	0	1	1	1
CE	1	1	*	1	1	1
SV	0	0	0	*	1	0
Y1	0	0	0	0	*	0
AV	1	0	0	1	1	*

Table 4: Quantity of Spares

	CV	IV	CE	SV	Y1	AV
CV	*	0	0	1	1	0
IV	1	*	1	1	1	0
CE	1	0	*	1	1	0
SV	0	0	0	*	0	0
Y1	0	0	0	1	*	0
AV	1	1	1	1	1	*

Table 5: Spare Part Cost

	CV	IV	CE	SV	Y1	AV
CV	*	1	0	1	1	1
IV	0	*	0	1	0	0
CE	1	1	*	1	1	1
SV	0	0	0	*	0	0
Y1	0	1	0	1	*	1
AV	0	0	0	1	0	*

To obtain multiple criteria preference index Π_{a1a2} (See Table 6) equation 5 was used.

Table 6: Final Matrix

	CV	IV	CE	SV	Y1	AV
CV	*	0.279687511	0	1	1	0.27968751
IV	0.720312489	*	0.093616	1	0.720312	0.62669647
CE	1	0.906383982	*	1	1	0.90638398
SV	0	0	0	*	0.626696	0
Y1	0	0.279687511	0	0.373304	*	0.27968751
AV	0.720312489	0.093616018	0.093616	1	0.720312	*

Now by using equation (6) and (7), we have evaluated the leaving flow and the entering flow. The Table 7 contains results, which are as follows-

Table 7: Row Summation & Column Summation

	CV	IV	CE	SV	Y1	AV	ϕ+
CV	*	0.279687511	0	1	1	0.27968751	2.559375023
IV	0.720312489	*	0.093616	1	0.720312	0.62669647	3.160937466
CE	1	0.906383982	*	1	1	0.90638398	4.812767964
SV	0	0	0	*	0.626696	0	0.626696471
Y1	0	0.279687511	0	0.373304	*	0.27968751	0.932678552
AV	0.720312489	0.093616018	0.093616	1	0.720312	*	2.627857013
ϕ-	2.440624977	1.559375023	0.187232	4.373304	4.067321	2.09245548	*

RESULTS & DISCUSSIONS

We have used equation (8) and evaluated the net flow or domination. The rank 1 is assigned to the component with highest net domination. Here we have obtained compressor element of this screw compressor as most critical one among others. The Table 8 and figure 2 illustrates results, which are as follows-

Table 8: Ranking of Components by PROMETHEE

	CV	IV	CE	SV	Y1	AV
Net Domination = ϕ+ - ϕ-	-0.134642896	2.601562443	5.625536	-4.18723	-3.57527	0.2820086
Ranking	4	2	1	6	5	3

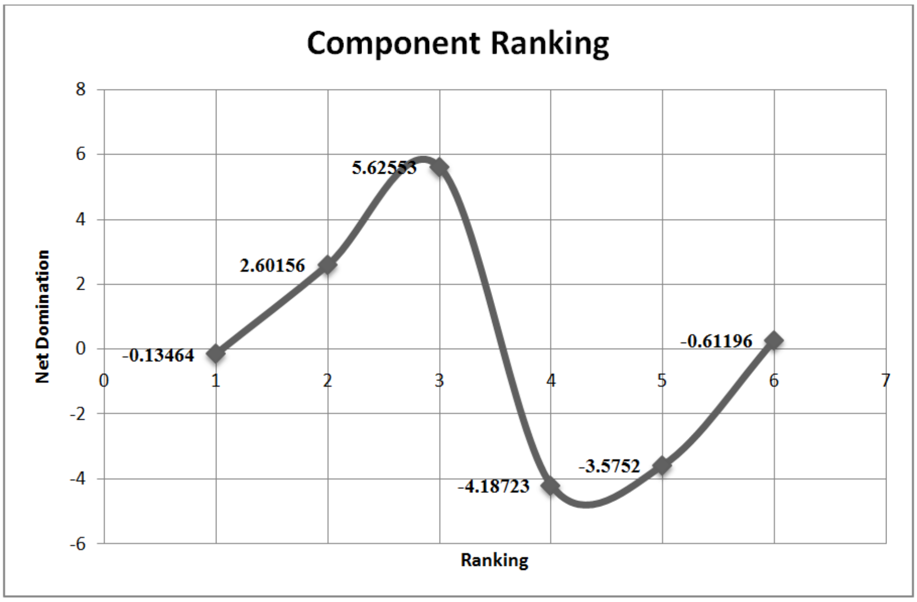

Figure 2: Component Ranking

CONCLUSIONS

This paper covers the use of analytical hierarchy process (AHP) for calculating weights and then, use of these weights with PROMETHEE method to identify critical component of the compressor to enhance equipment availability in a production industry. We have identified the compressor element (CE) as the most critical component of screw compressor. Apart from this, this is a generalized approach. Therefore, application of similar approach in other industries can be done by other researchers.

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